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OF
CIVIL ENGINEERS

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Vol. II SEPTEMBER, 1915 No. 7.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, SEPTEMBER 15, 1915,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. M. J. Lorente, C.E., will read a paper entitled, "Some Special Methods of Reinforced Concrete Design." The paper is printed in this issue of the JOURNAL.

S. E. TINKHAM, *Secretary.*

PAPERS IN THIS NUMBER.

"Special Methods of Reinforced Concrete Design," M. J. Lorente. (To be presented September 15, 1915.)

Discussion of "Ground Water Supplies."

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

Boston, Mass., June 16, 1915.—A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Charles R. Gow, at 8 o'clock. There were 63 members and visitors present.

By vote the reading of the record of the last meeting was waived, and the record as printed in the June Journal was approved.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Honorary member—Past President Desmond FitzGerald.

Members—Messrs. Gale Augustus Carter, John H. Coghlan, Elias Francis De La Haye, Jr., Harry C. Foster, Joseph Francis Aloysius Leonard and Charles Frederick Parker.

Associate—Mr. George Woodward Langdon, Jr.

Juniors—Messrs. Harry Leon Katz and Max Silverman.

The Secretary announced the deaths of Theodore L. Keppler, an associate of the Society, who died May 24, 1915, and Lorenzo G. Moulton, a member, who died June 9, 1915. By vote the President was requested to appoint committees to prepare memoirs. The President has appointed committees as follows: On memoir of Mr. Keppler, Mr. Frederic I. Winslow; on memoir of Mr. Moulton, Mr. L. Lee Street.

The Librarian called attention to the rules now in force in relation to the circulation of books in the Society's library. These rules were adopted in 1896, and because of changed conditions in the library they are not now entirely satisfactory. On motion of Mr. Sherman, the Committee on the Library were empowered to make such rules in relation to the circulation of books in the library as they deemed advisable.

On motion of Mr. Wason, the thanks of the Society were voted to Mr. George A. Dodge for the admirable way in which he served the members of the Society and those of the New England Water Works Association on the occasion of the joint outing at Pemberton Inn on June 16, 1915.

The President then introduced Prof. Charles F. Binns, director of the New York State School of Clay Working and

Ceramics at Alfred University, Alfred, N. Y., who delivered a most entertaining and instructive address on "The Application of Clay Products to Some Engineering Problems." Among other topics taken up were, varieties of clay, preparation of clays, manufacture and testing of structural wares, terra-cotta, hollow tiles, paving bricks and the construction of brick pavements. The address was fully illustrated with lantern slides. At the close of the address, the thanks of the Society were extended to Professor Binns.

Vice-President Richard A. Hale presided during the latter portion of the meeting.

Adjourned.

S. E. TINKHAM, *Secretary.*

APPLICATIONS FOR MEMBERSHIP.

[September 3, 1915.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ALEXANDER, CLAYTON CLIFFORD, Medford, Mass. (Age 33, b. Killingly, Conn.) Student for three years at Univ. of Vermont, and for one year at Univ. of Maine, civil engineering course. From 1902 to 1903, instructor in civil engineering, Univ. of Maine; from 1903 to 1905, designing draftsman with General Electric Co., Schenectady, N. Y.; from 1905 to 1908, in charge of party on Panama Canal with Isthmian Canal Comm.; from 1908 to 1910, with Cheney Bigelow Wire Works, Springfield, Mass., in charge of drafting; from 1911 to 1913, with Providence Steel and Iron Co., estimating and designing on roofs and bridges; during summer and fall of 1914, inspector of Springfield underpasses with S. H. Pitcher Engineering Co; is now second assistant city engineer, Woonsocket, R. I. Refers to F. A. Caldwell, C. F. Parker, L. K. Rourke and Arnold Seagrave.

ALLARDICE, JAMES PROCTOR, Fall River, Mass. (Age 24, b. Fall River, Mass.) Graduate of Worcester Polytechnic Inst., 1915, civil engineering course. During summer vacation, 1913, rodman and instrumentman; from June, 1914, to March, 1915, instrumentman and chief of party with E. M. Corkett, C.E., Fall River; from March, 1915, to date, force accountant on Fall River Intercepting Drain with Barrows & Breed, Boston. Refers to V. J. Gallene, H. C. Ives, A. J. Knight, H. L. Robinson, G. S. Sawyer and A. L. Shaw.

BARNEY, HAROLD BRYANT, Chestnut Hill, Mass. Age 29, b. Roxbury, Mass.) Graduate of Harvard, 1908, degree of A.B.; received degree of S.B. in civil engineering from Lawrence Scientific School, 1909. From 1909 to Dec., 1913, draftsman, inspector, division engineer, etc., with Stone & Webster Engrg. Corp'n at Seattle, Wash., and in California; from June, 1914, to date, with Warren Bros. Co., of Boston, as timekeeper, etc. Refers to H. K. Alden, L. E. Baker, L. J. Johnson and C. E. Nichols.

BENNETT, RAYMOND FRANKLIN, Portland, Me. (Age 39, b. Freeport, Me.) Graduate of Mass. Inst. of Technology, 1899, civil engineering course. From 1892 to 1899, worked during summers with various surveying parties; for nine months during the year 1900, draftsman with Bridge Dept., N. Y., N. H. & H. R. R.; since Nov., 1900, member of firm of W. F. Bennett & Son, contractors for pile driving, wharf building, etc. Refers to P. A. Babcock, Richard Brunel, L. F. Ellis and E. E. Pettee.

COLBY, EDWIN WHITMORE, Boston, Mass. (Age 24, b. Medford, Mass.) Student in structural engineering for four years at Franklin Union. From June, 1908, to Aug., 1910, with Whitman & Howard, as rodman, instrumentman and draftsman; from Aug., 1910, to March, 1912, inspector with Edison Electric Ill. Co., on underground conduit construction; from March, 1912, to March, 1915, with Whitman & Howard, as assistant engineer on street railway surveys and construction, highway surveys, topographical surveys, etc.; from March, 1915, to date, with Metropolitan Water Works, as assistant engineer. Refers to Randolph Bainbridge, Benjamin Boas, W. E. Foss, Channing Howard, E. H. Rockwell, R. C. Smith and F. A. Snow.

HOWARD, DAVID RUSSELL, Woonsocket, R. I. (Age 29, b. Fall River, Mass.) Received education in public schools. From March, 1904, to Jan., 1911, with E. K. Watson Co., building contractors, Warren, R. I., first as timekeeper and later as assistant to engineer; in Jan., 1911, incorporated the Eastern Construction Co., Woonsocket, R. I., and became one of its directors; since that time has acted as president, treasurer and general manager of that company. Refers to F. A. Caldwell, F. H. Mills, C. F. Parker and Arnold Seagrave.

Makepeace, Bertrand L., Brookline, Mass. (Age 43, b. Foxboro, Mass.) From 1895 to date has been engaged in manufacture of blue prints and black-line prints for engineers, architects, etc., during which time has added to this line drawing materials and surveying instruments; in 1911 equipped machine shop for manufacturing, overhauling, repairing and rebuilding surveying instruments; is specialist in engineers' goods and scientific instruments. Refers to E. M. Blake, Channing Howard, J. J. Van Valkenburgh and W. F. Williams.

Walker, Frank Bates, Winthrop, Mass. (Age 41, b. Traverse City, Mich.) Graduate of Univ. of Minnesota, 1897, degree of C.E.; student in mining engineering, 1899 and 1900, at Mass. Inst. of Technology. Later held subordinate positions in Engineering Depts. of M. & St. L. R. R. and M., St. P. & S. S. M. R. R.; from 1897 to 1898, assistant engineer and chemist on blast-furnace work for Cleveland Cliffs Iron Co.; for fifteen years, assistant and resident engineer on Great Northern R. R.; since spring of 1914, assistant engineer in charge of bridge work, etc., for Bay State Street Ry. Refers to H. W. Hayes, A. W. Hodges, L. E. Moore and J. R. Worcester.

LIST OF MEMBERS.

ADDITIONS.

Burroughs, Russell.................Concord, N. H.
Carter, Gale A.................Box 183, Colebrook, N. H.
Coghlan, John H.................Lowell St., Lexington, Mass.
De La Haye, Elias F., Jr.................38 Intervale St., Roxbury, Mass.
Farwell, Joseph W.................1803 Washington St., Canton, Mass.
Foster, Harry C.................Western Ave., Gloucester, Mass.
Harty, John J., Jr.................310 Technology Chambers, Boston, Mass.
Katz, Harry L.................100 Granville Ave., Malden, Mass.
Leonard, Joseph F. A.................4011 No. Main St., Fall River, Mass.
O'Neil, Thomas P.................10 Fairfield St., Cambridge, Mass.
Parke, Robert H.................59 Milk St., Fitchburg, Mass.
Silverman, Max.................26 Lawrence Park, Dorchester, Mass.
Whitney, Harry L.................38 Wallace St., Somerville, Mass.

CHANGES IN ADDRESS.

Adams, Edward P.................1112 Exchange Bldg., Boston, Mass.
Barnes, Roderick S.................Randolph, N. H.
Bayley, Frank A.................Box 330, Hyannis, Mass.
Bowers, George W.................3200 Franklin Ave., Cleveland, Ohio

Cashman, John M. .... 14 Beacon St., Boston, Mass.
Drummond, John M. .... 30 Orchard St., Jamaica Plain, Mass.
Goodell, John M. .... 106 Lorraine Ave., Upper Montclair, N. J.
Morse, Charles F. ...... Hotel Pontiac, Good Ground, Suffolk Co., N. Y.
Pinkham, Millard B. .... 141 Monroe St., Brooklyn, N. Y.
Sokoll, Jacob M. .... 239 Shelton Ave., New Haven, Conn.
Stratton, George E. .... Saco, Mont.
Treadwell, Edward D.,
Engineer's Office, City Hall, Webster Groves, Mont.
Winsor, Frank E. .... 228 Atlantic Ave., Providence, R. I.

DEATHS.

Keppler, Theodore L. .... May 24, 1915
Moulton, Lorenzo G. .... June 9, 1915
Brackett, Dexter .... August 26, 1915

EMPLOYMENT BUREAU.

The Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

316. Age 29. Student for three years in civil engineering courses at Harvard Univ.; student in evening courses in mechanical and electrical engineering at Mass. Inst. of Technology. Is junior member of Am. Soc. C. E. and associate member of Am. Inst. E. E. Experience includes one year as transitman of Metropolitan Water and Sewerage Bd. and six years on electric railway work as draftsman, chief of party, resident engineer, superintendent of underground construction, etc. Desires position in line with this experience.

317. Age 20. Student for two years at Tufts College. Experience consists of six months' field work and three months' class work at Tufts. Desires position as rodman. Salary desired, $8 per week.

320. Age 26. Student for four years at Dartmouth College and for

one year at Thayer School of Civil Engineering. Has had nearly three years' experience, including four months as chainman on construction with New Haven R. R. Co., and more than two years as draftsman with iron and steel company. Desires position on construction work. Salary desired, $70 per month.

321. Age 23. Graduate of Univ. of Maine, 1915. Has had some experience during summer vacations as rodman with Bay State Street Ry. Co., and as draftsman with Mass. Harbor and Land Comm. Desires position as rodman, transitman or draftsman. Salary desired, $2 per day.

324. Age 33. Received education at universities of Maine and Vermont. Has had about thirteen years' experience, including three years with Providence Steel and Iron Co. on roof and bridge design; one and one-half years with Cheney Bigelow Wire Works on design of elevators and elevator enclosures; eight months as assistant engineer in charge of field work for the City of Woonsocket, R. I.; one year as instructor in civil engineering, Univ. of Maine; and five years of municipal and construction work; is familiar with concrete construction. Salary desired, $1,200 per year.

325. Age 26. Received technical education from I. C. S. courses. Has had seven years' experience as a transitman; considers himself good draftsman and letterer. Salary desired, $3 per day.

326. Age 29. Received degree of B.S., Univ. of Vermont, 1909. Experience includes one year on dam, bridge and road construction; nine months with N. Y. C. & H. R. R. R. on grade-crossing work; one year as resident engineer with Grand Trunk Pacific Ry.; and fifteen months on New York subways. Desires position as assistant engineer. Salary desired, $115 per month.

327. Age 21. Was student for two years at Lowell Inst.; is now student in I. C. S. course in concrete engineering. Experience includes two and one-half years as draftman and estimator; six months as chainman and rodman; four months as labor foreman; has passed state examination as junior engineer. Desires position as timekeeper, rodman or estimator. Salary desired, $12 per week.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Abstract of Special Bulletins on Wealth, Debt and Taxation, 1913.

Analysis and Grading of Creosotes. Arthur L. Dean and Ernest Bateman.

Annual Reports of Reclamation Service for 1912–13 and 1913–14.

Coalville Coal Field, Utah. Carroll H. Wegemann.

Contributions to Economic Geology, 1913: Part I. Metals and Non-metals except Fuels. F. L. Ransome and Hoyt S. Gale.

Cypress and Juniper Trees of Rocky Mountain Region. George B. Sudworth.

Progress Reports of Experiments in Dust Prevention and Road Preservation, 1914.

Estimation of Moisture in Creosoted Wood. Arthur L. Dean.

Eucalypts Cultivated in United States. Alfred James McClatchie.

Geology and Coal Resources of North Park, Colorado. A. L. Beekly.

Gold-Platinum-Palladium Lode in Southern Nevada. Adolph Knopf.

Utilization and Management of Lodgepole Pine in Rocky Mountains. D. T. Mason.

Production of Lumber in 1913.

Mineral Deposits of Santa Rita and Patagonia Mountains, Arizona. Frank C. Schrader.

Naval Stores Industry. A. W. Schorger and H. S. Betts.

Oil-Mixed Portland Cement Concrete. Logan Waller Page.

Preservative Treatment of Loblolly Pine Cross-Arms. W. F. Sherfesee.

Primer of Wood Preservation. W. F. Sherfesee.

Portland Cement Concrete Pavements for Country Roads. Charles H. Moorefield and James T. Voshell.

Relation of Southern Appalachian Mountains to Development of Water Power. M. O. Leighton, M. R. Hall and R. H. Bolster.

Rules and Specifications for Grading of Lumber. E. R. Hodson.

Seasoning of Timber. Hermann von Schrenk.

Results of Spirit Leveling in Idaho, 1896 to 1914, inclusive. R. B. Marshall.

Results of Spirit Leveling in Minnesota, 1897 to 1914, inclusive. R. B. Marshall.

State Management of Public Roads: Its Development and Trend. J. E. Pennybacker.

Water Supply Papers 222, 225, 226, 239, 276, 279, 282, 286, 291, 294, 298, 340-D, 340-H, 340-I, 340-J, 345-H, 345-I, 375-A. Twelve numbers gift of C. W. Sherman.

What Forestry has Done. Treadwell Cleveland, Jr.

Wood Using Industries of New Jersey. Albert H. Pierson.

State Reports.

Maine. Annual Report of Railroad Commissioners for 1914.

Massachusetts. Annual Report of Gas and Electric Light Commissioners for 1914.

Massachusetts. Annual Report of Harbor and Land Commissioners for 1914.

Massachusetts. Annual Report of Metropolitan Park Commission for 1914.

Massachusetts. Annual Report of Metropolitan Water and Sewerage Board for 1914.

New Jersey. Geology of New Jersey, 1915. J. Volney Lewis and Henry B. Kümmel.

New Jersey. Indian Habitations in Sussex County. Max Schrabisch.

New York. Annual Reports of Public Service Commission for First District: Vol. II for 1913 and Vol. I. for 1914.

New York. State Department of Labor, Industrial Board: Rules on Sanitation of Factories and Mercantile Establishments.

North Dakota. Reports and Bulletins of Agricultural Experiment Station as follows: Annual Report for 1912, Part III: Waters, Wheats, Paints, Oils, and Farm Products; North Dakota Paint Tests; Paints and their Compositions, by E. F. Ladd and C. D. Holley; Some Ready Mixed Paints, by E. F. Ladd and G. A. Abbott; Paints: Their Service Condition, by E. F. Ladd and E. E. Ware; Paint Bulletins 1 to 4, and Vol. I, 5 and 6.

Rhode Island. Annual Report of Commissioner of Dams and Reservoirs for 1912.

Rhode Island. Annual Reports of Railroad Commissioner for 1895, 1896, 1899, 1901–11, inclusive.

Rhode Island. Annual Reports of Public Utilities Commission, 1912–14, inclusive.

Wisconsin. Geological and Natural History Survey: Limestone Road Materials of Wisconsin. W. O. Hotchkiss and Edward Steidtmann.

Municipal Reports.

Baltimore, Md. Annual Report of Sewerage Commission for 1914.

Bangor, Me. Annual Report of Water Board for 1914.

Beverly, Mass. Annual Report of Department of Public Works for 1914.

Boston, Mass. Annual Report of City Planning Board for 1914.

Brockton, Mass. Annual Reports of City Engineer and Sewerage Commissioners for 1911, 1912 and 1914.

Cambridge, Mass. Report of Special Committee on Study of Local Real Estate Assessment Situation. Gift of C. M. Spofford.

Fall River, Mass. Annual Report of Watuppa Water Board for 1914.

Marlborough, Mass. Annual Report of Water and Sewage Commission for 1914.

Medford, Mass. Annual Report of Water and Sewer Department for 1914.

New Orleans, La. Semi-Annual Report of Sewerage and Water Board, December, 1914.

New York, N. Y. Annual Report of Board of Water Supply for 1914.

New York, N. Y. Annual Report of Department of Water Supply, Gas and Electricity for 1914–15.

Northampton, Mass. Annual Reports of City Officers for 1914.

Northampton, Mass. Annual Report of Water Commissioners for 1914.

Philadelphia, Pa. Report on Collection and Treatment of Sewage, 1914.

Philadelphia, Pa. Annual Report of Bureau of Surveys for 1914.

Providence, R. I. Annual Reports of City Engineer and of Commissioner of Public Works for 1908–14. 2 vols. Gift of Otis F. Clapp.

Waltham, Mass. Annual Reports of City Engineer for 1914.

Woburn, Mass. Annual Report of Water Department for 1914.

Worcester, Mass. Report of Special Commission on Collection and Disposal of Municipal Waste, 1914. Gift of Frederic Bonnet, Jr.

Miscellaneous.

American Society of Mechanical Engineers: Rules for Construction of Stationary Boilers and for Allowable Working Pressures, 1914.

Apportionment of Cost of Highway Bridges between Street Railways and Cities. Charles M. Spofford. Gift of author.

De Aquaeductibus Urbis Romae Commentarius. Sextus Iulius Frontinus. Gift of Desmond FitzGerald.

Babcock & Wilcox Co.: Steam Superheaters.

Brooklyn Engineers' Club: Proceedings for 1914.

Canada, Department of Mines: Petroleum and Natural Gas Resources of Canada, Vol. I, by Frederick G. Clapp and Others; Products and By-Products of Coal, by Edgar Stansfield and F. E. Carter.

Determination of Biochemical Oxygen Demand by Saltpeter Method in Stockyards, Tannery and Corn Products Wastes. Arthur Lederer.

Plan for Functional Organization of Engineering Work of City of New York. William W. Bush.

Great Lakes Dredge and Dock Co.; Premolded Reinforced Concrete Piles and Poles.

National Board of Fire Underwriters: Progress Report on Follow-up Work and Reports on following cities: Akron, Ohio; Alexandria, Va.; Allentown, Pa.; Atlanta, Ga.; Augusta, Ga.; Bay City, Mich.; Bloomington, Ill.; Camden, N. J.; Canton, Ohio; Charleston, W. Va.; Chattanooga, Tenn.; Chester, Pa.; Columbus, Ohio; Danville, Ill.; Dayton, Ohio; Detroit, Mich.; Duluth, Minn.; East St. Louis, Ill.; Easton, Pa.; Flint, Mich.; Fort Wayne, Ind.; Grand Rapids, Mich.; Hamilton, Ohio; Hannibal, Mo.; Haverhill, Mass.; Holyoke, Mass.; Indianapolis, Ind.; Jacksonville, Fla.; Knoxville, Tenn.; Lawrence, Mass.; Lima, Ohio; Louisville, Ky.; Lynn, Mass.; Montgomery, Ala.; New Castle, Pa.; New Orleans, La.; New Rochelle, N. Y.; Newark, Ohio; Philadelphia, Pa.; Pittsfield, Mass.; Portsmouth, Ohio; Pottsville, Pa.; Roanoke, Va.; Saginaw, Mich.; St. Louis, Mo.; St. Paul, Minn.; Salem, Mass.; Savannah, Ga.; Sheboygan, Wis.; Shreveport, La.; Springfield, Ohio; Superior, Wis.; Tampa, Fla.; Toledo, Ohio; Waltham, Mass.; Watertown, N. Y.; Wheeling, W. Va.; Williamsport, Pa.

Notes on Practical Application of "Saltpeter Method" for Determining Strength of Sewages. Arthur Lederer.

Some Paint and Painting Factors. H. Lowe.

Permeability Tests on Gravel Concrete. Morton O. Withey.

Our late Past President, Alexis H. French, has bequeathed to the Society the sum of one thousand dollars, the income of which is to be at the disposal of Mrs. French during her lifetime, and after that to be devoted to the improvement of the Society's library.

The Society has also had two bequests from the estate of our late associate, Edmund K. Turner, one of the sum of one thousand dollars — the income of same to be used for the library — and the other of the engineering books in his library, numbering over one thousand volumes. It has not been deemed advisable to publish in the JOURNAL the list of titles of these volumes, on account of its length, but the list may be consulted at the Society rooms.

In accordance with the vote passed at the last meeting, authorizing the Committee on the Library to make such rules in relation to the circulation of books in the library as they deemed advisable, the following rules have been adopted:

Books and periodicals may be used in the Society rooms by members and friends.

Members may borrow books for home use — with the exceptions noted below — but no one shall have more than four books at any time, or keep any book more than two weeks.

Volumes belonging to a set — such as volumes of bound periodicals and of proceedings or transactions of societies — and such other books as the Board of Government may designate, may be taken from the rooms for a limited time only, by special arrangement with the attendant. They shall be subject to recall at any time.

There shall be no immediate renewal of any book on its return to the library.

A member borrowing a book shall at that time give a receipt therefor.

A fine of one cent per day per volume shall be charged for overtime, and must be paid before the delinquent can take any more books.

Handbooks, indexes, current numbers or unbound files of periodicals, books belonging to the Clemens Herschel Special Library, and new books not yet placed on the regular shelves must not be taken from the rooms.

Books of unusual value are marked with a star (*), and must not be taken from the rooms, except by written permission from the Librarian, to be filed by the attendant.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules may, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

(Revised June 16, 1915.)

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.— METROPOLITAN WATER AND SEWERAGE BOARD.—*Sewerage Works.* Work is in progress on Sections 105 and 106 of the Wellesley Extension Sewer.

Work contemplated consists of lowering the Malden River siphon and extending the Deer Island outfall sewer.

METROPOLITAN PARK COMMISSION. — *Charles River Reservation.* — Plans and specifications have been prepared, and it is expected to call for bids in the near future for bridge over the Charles River at North Beacon St., Boston and Watertown.

Plans and specifications are being prepared for bridge over the Charles River at Commonwealth Ave., between Newton and Weston.

Furnace Brook Parkway. — Work of constructing parkway extension from Quincy Shore Reservation to Hancock St. is in progress. John Cashman & Sons Co., contractors.

Contract for building reinforced concrete girder bridge across Blacks Creek, for Furnace Brook Parkway Extension, has been awarded to the Hugh Nawn Contracting Co., and work will commence immediately.

Mystic Valley Parkway. — Work of constructing parkway from Cradock Bridge to Mystic Ave. is in progress. Coleman Brothers, contractors.

Contract has been awarded to Coleman Brothers for excavating and dredging the channel of Aberjona River from Boston & Maine Railroad to Walnut St., Winchester. Work is to be commenced immediately.

Revere Beach Reservation. — Bids have been received for building reinforced-concrete shore protection of the bleacher form at Revere Beach Reservation.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY

Division, Paving Service. — Work is in progress on the following streets:

West Broadway,	Dorchester Ave. to Dorchester St.	Art. stone sidewalks.
Idlewild St.,	Commonwealth Ave. to Brainerd Rd.	Bitulithic.
Lake St.,	Commonwealth Ave. to Washington St.	Art. stone sidewalks.
Spring St.,	Gardner St. to Webster St.	Bituminous macadam.
Temple St.,	Spring St. to Ivory St.	Excavating and grading.
Hillcrest St.,	Elgin St. to Temple St.	Excavating and grading.
Howitt Rd.,	Bellevue St. to LaGrange St.	Bituminous macadam.
Chapin Ave.,	Mt. Vernon St. to Preston Rd.	Tar macadam.
Fletcher St.,	Centre St. to Montclair Ave.	Bituminous macadam.
Pelton St.,	Park St. to W. Roxbury Parkway.	Bituminous macadam.
Park St.,	Centre St. to Montview St.	Art. stone sidewalks.
Augustus Ave.,	Poplar St. to beyond Clarendon St.	Tar macadam.
Birch St.,	Penfield St. to Dudley Ave.	Bitulithic pavement.
Poplar St.,	Sycamore St. to Brown Ave.	Art. stone sidewalks.
Oakland St.,	River St. to Rockdale St.	Bituminous macadam.
Seaver St.,	Blue Hill Ave. to Walnut Ave.	Excavating and grading.
Claxton St.,	Blue Hill Ave. to Callender St.	Asphalt pavement.
Callender St.,	Claxton St. to Tucker St.	Art. stone sidewalks.
Claybourne St.,	Dakota St. to Park St.,	Bitulithic pavement.
Lithgow St.,	Talbot Ave. to Wainwright St.	Excavating and grading.
Peacevale Rd.,	Norfolk St. to Dunbar Ave.	Asphalt pavement.
Lingard St.,	Magnolia St. to Hartford St.	Bitulithic pavement.
Public Alley No. 908,	Mass. Ave. to Marlborough St.	Brick block pavement.

Public Works Department, Sewer and Water Division, Sewer Service. — The following work is in progress:

In Delhi St., Mattapan; Mattapan Brook Conduit, 4′–9″, 4′–6″ and 4′–3″ circular concrete, and 15″ and 12″ pipe sanitary sewer.

Richfield and Westwood Sts., Dorchester, circular concrete surface drain, 3′–9,″ 3′–6″ and 3′–3″.

Temple St. Brook Conduit in Chiswick Rd., Tarleton and Elgin Sts., West Roxbury, sizes 6′–0″ to 3′–6″ circular concrete.

Glendower Rd., West Roxbury, 3′–3″ circular concrete surface drain.

Condor St., East Boston, 2′–6″ circular concrete surface drain and 10″ pipe sanitary sewer.

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PAPERS AND DISCUSSIONS

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SOME SPECIAL METHODS OF REINFORCED CONCRETE DESIGN.

By M. J. Lorente.*

(To be presented September 15, 1915.)

The field of reinforced concrete has proved a sort of Promised Land to the modern engineer, especially if he be young, energetic and ambitious.

Until a very few years ago, the subject was practically a novelty and only a few pioneers had ventured to explore its mysteries. But, as is usually the case when an exploration leads to an important and lucrative discovery, the pioneers were soon followed by a host of the rank and file of the profession, eager for both the laurels and the pelf which they imagined to be easy of acquisition in the newly discovered field. However, in spite of this invasion of eager workers, the field still remains a wide one, as shown by the very many points on which authorities disagree. A notable instance of this is the "Mushroom System," which mushroom, by the way, must belong to one of the poisonous varieties, to judge by the innumerable and bitter discussions which have been raging about it.

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Note. This paper is issued in advance of the date set for its presentation. Discussion is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before November 10, 1915, for publication in a subsequent number of the Journal.

Unfortunately, those who style themselves with the well-nigh comprehensive title of "Civil Engineer" must be, above all, practical men. By this I do not mean to cast a slur on the members of the other branches of engineering. What I mean is that the civil engineer, in order to be successful and make a name for himself, must be in actual practice and in such a position as to be able to carry his ideas into effect. A mechanical engineer can theorize *ad libitum* and proceed to put his ideas into practice by means of models which may be within the reach of a moderate income, but the nature of a civil engineer's work is such that models are of practically no use whatsoever. He must, as a rule, experiment on full-sized structures, which, of necessity, entail a considerable expenditure of money, and for this reason most civil engineers have to content themselves with theorizing till Dame Fortune offers them the opportunity to give their ideas tangible form. Dame Fortune being somewhat sparing with her favors, the majority of us must perforce remain satisfied with theorizing, and this is perhaps the chief reason why reinforced concrete literature is so abundant, especially as regards methods of design.

It is with a certain degree of timidity, therefore, that I venture to add my little quota to reinforced concrete literature by offering to the members of this Society a few suggestions which will tend to facilitate the design of T-beams and of beams with steel in compression.

The method universally employed in analyzing reinforced concrete beams with steel in the tension side only has given rise to a few simple formulæ which render the operation of design extremely simple. If we know the values of R, the coefficient of resistance, and of p, the ratio of cross-sectional area of steel in tension to cross-sectional area of beam, for any given stresses, we can find the beam section to resist a given bending moment in an extremely short time. And as both R and p can easily be tabulated for various stresses, the design of such beams is simplicity itself.

It must be noticed that, in order to tabulate the values of R and p, we must find the value of the arm of the internal couple which resists the bending forces. Because of the uniformity of the material on the compression side and of the simple geometry of a rectangular beam reinforced on the tension side only, the value of the arm can easily be found. But when we come to consider beams with steel in the compression side and T-beams, the values of the arms of the resisting couples are exceedingly troublesome quantities to deal with. In one case the heterogeneousness of the materials in the compression side, and in the other, the comparatively intricate geometry of the cross-section of the beam, complicate the expressions for the arm to such an extent as to make them absolutely impractical.

In dealing with beams with steel in compression and T-beams, authorities have thus far followed the same analytical methods used in deriving expressions for beams with steel in tension only and their efforts have been rewarded with such formulæ as the following one which gives the value of the arm of the resisting couple in a T-beam:

$$Kd=\sqrt{\frac{2ndA_s+(b_1-b)t^2}{b}+\left(\frac{nA_s+(b_1-b)t}{b}\right)^2}-\frac{nA_s+(b_1-b)t}{b}$$

from which it would appear that the arm of a T-beam looks as fearsome and is as long as the famous "arm of the law."

Such a formula seems calculated to strike terror into the heart of a designer and is a contributory cause to the sneering attitude assumed by the so-called practical man towards his technical brother. And in this case the practical man, we must confess, is perfectly justified in his attitude, for the formula has none but an academic value. As a matter of fact, it is absolutely unnecessary to find the values of the arms of the resisting couples of beams with steel in compression and of T-beams, and their design can best be accomplished by entirely ignoring such values. This I propose to demonstrate in the following explanation of methods which I believe are entirely new.

DESIGN OF T-BEAMS.

Let us have a T-beam *ABHGJIFE* (Fig. 1).

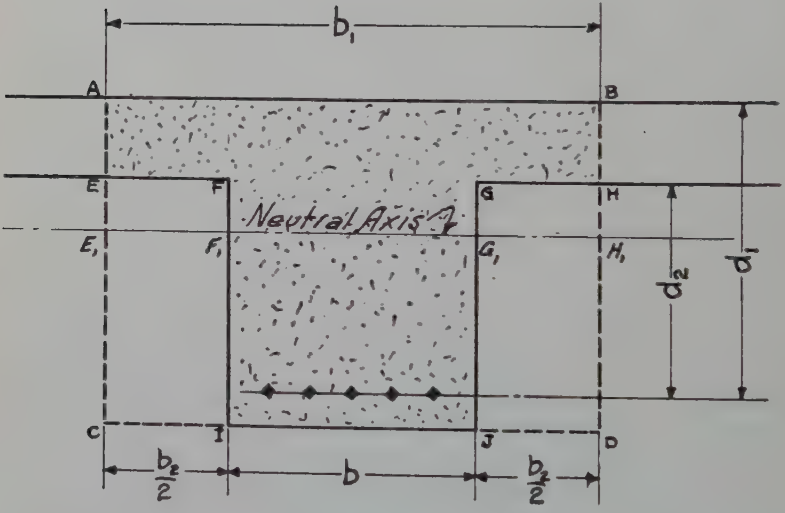
The moment of resistance of the "T" will clearly be equal to that of a rectangular beam *ABDC* less those of two rectangular beams *EFIC* and *HDJG*.

Likewise, the area of steel required for the "T" will be that required for a rectangular beam *ABDC* less that required for the two beams *EFIC* and *HDJG*. That these statements are correct can be proven by the elementary principles of beam sections thus:

$$\text{R. M.} = \frac{E}{\rho}\Sigma a y^2 + \frac{E}{\rho}\Sigma a_1 (y^1)^2$$

$$= \frac{f}{y}\Sigma a y^2 + \frac{f_1}{y_1}\Sigma a_1 (y^1)^2$$

$$\text{or} \quad = \frac{f_c}{y_c}\Sigma a_c y^2 + \frac{f_s}{y_s}\Sigma a_s (y^1)^2.$$



—Fig. 1—

In the T-beam Σa_c will be the area $AE_1H_1B—EE_1F_1F—GG_1H_1H$, and Σa_s will be the area of steel required for the large beam less the areas required for the smaller beams. We thus have reduced to rectangular beams the problem of a T-beam.

Expressing the above statements in formulæ, we have:

$$M = R_1 b_1 d_1^2 - R_2 b_2 d_2^2$$

and

$$A = p_1 b_1 d_1 - p_2 b_2 d_2,$$

where

M = bending moment in inch-pounds;
A = required area of steel in square inches;
R_1 = coefficient of resistance for the large beam ($ABDC$);
R_2 = coefficient of resistance for the small beams ($EFIC$ and $HDJG$);
p_1 = ratio of area of steel to effective area of beam $ABDC$;
p_2 = ratio of area of steel to effective area of beams $EFIC$ and $HDJG$.

It should be borne in mind that the steel stresses will be the same for both the large and the small beams, but the stresses in the concrete will be different. In the large beam the stress will be the maximum allowable, while in the small beams the stresses will be those corresponding to the fibers in the underside of the slab forming the wings of the "T." If we know the position of the neutral axis we can easily find them by simple proportion. Now it is this stress in the concrete in the under side of the slab which determines the values of R_2 and p_2.

Suppose, now, that we had a table giving the values of the constants R, p and k (where k is the coefficient which, multiplied by the effective depth of the beam, gives the depth of the neutral axis below the top of the beam) for a given stress in the steel and a given ratio of moduli. Then, after determining by simple proportion the stress in the under side of the slab we could pick out the required constants. If we had a beam 25 ins. deep and with a slab 6 ins. deep, and if the allowable stresses were 18 000 lbs. per sq. in. for the steel and 800 lbs. per sq. in. for the concrete, and the ratio of moduli were 12, we would find that the stress in the under side of the slab would be—

$$\left(k - \frac{t}{d}\right)\frac{f_c}{k} = 250 \text{ lbs. per sq. in.,}$$

where t is the thickness of the slab. Then from the accompanying Table 1 we could obtain directly the constants—

$$R_1 = 123, \ p_1 = 0.0077, \text{ and } R_2 = 17, \ p_2 = 0.001.$$

In order to avoid interpolating for values not given in the table, and to simplify at the same time the operation for finding the stress in the underside of the slab, a set of curves could be made for given stresses in the steel and given ratios of moduli similar to those shown in Figs. 2 to 7, inclusive. The method of using the curves is as follows.

Along the scale of $\frac{t}{d}$ take the required value. From this point follow a perpendicular line till it meets the oblique line marked with the maximum stress allowable in the concrete. From this point of intersection follow a line parallel to the scale of $\frac{t}{d}$ till it meets the curves marked R and p, and read the corresponding values in the respective scales. These values are those of R_2 and p_2. The values of R_1 and p_1 can be obtained by following a parallel line from the point where the oblique line marked with the maximum allowable stress in the concrete meets the perpendicular from the zero point of the $\frac{t}{d}$ scale.

In actual practice, the formulæ given above have to be slightly modified. Thus, if we want to design a beam we have—

$$M = R_1 b d_1^2 + R_1 b_2 d_1^2 - R_2 b_2 d_2^2;$$
$$A = p_1 (b + b_2) d_1 - p_2 b_2 d_2.$$

For purposes of reviewing a beam, the formulæ as already given are sufficient.

It should be noticed that this method, besides being simpler than those in common use, does not neglect the compression in the stem of the beam.

Design of Beams with Steel in Compression.

Referring to Fig. 8, showing the cross-section of a beam reinforced with steel in the compression side, the moment of resistance of the concrete in compression is

$$\tfrac{1}{2} bkjd^2 f_c,$$

and the moment of resistance of the steel in compression is

$$\frac{p^1 bd^2 r f_c n (kd - d + rd)}{kd}$$

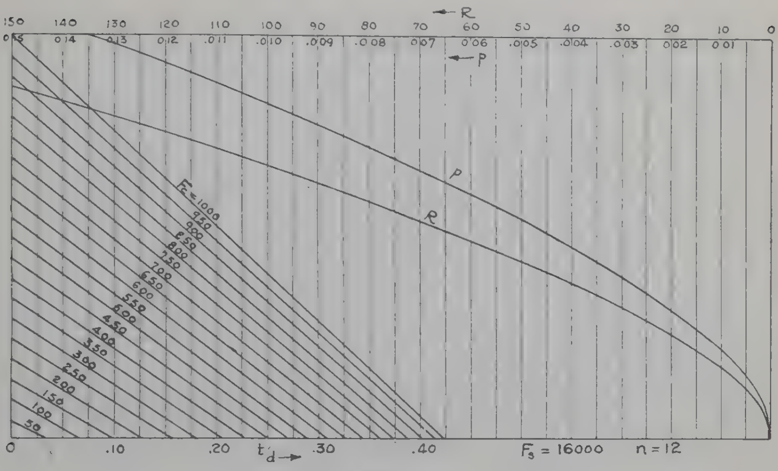

← R
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.15
0.14
0.13
0.12
.011
.010
.009
.008
0.07
0.06
.005
.004
.003
0.02
0.01
← p
p
R
Fc = 1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
.10
.20
t/d →
.30
.40
Fs = 16000
n = 12

FIG. 2.

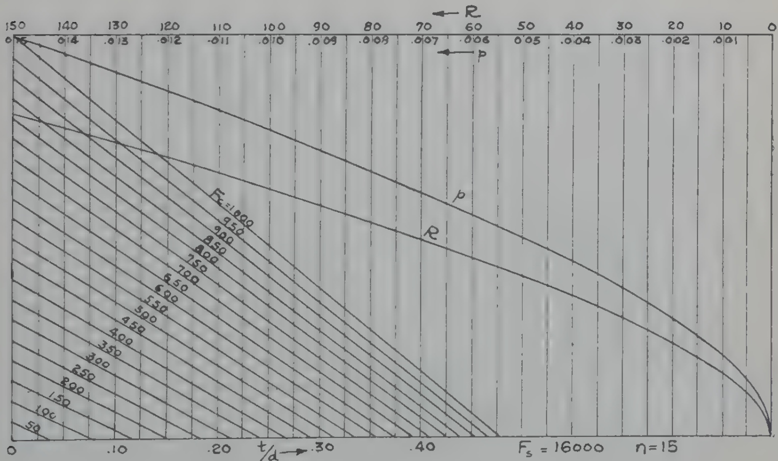

← R
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.15
0.14
.013
.012
.011
.010
.009
.008
.007
.006
0.05
.004
.003
.002
.001
← p
p
R
Fc = 1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
.10
.20
t/d →
.30
.40
Fs = 16000
n = 15

FIG. 3.

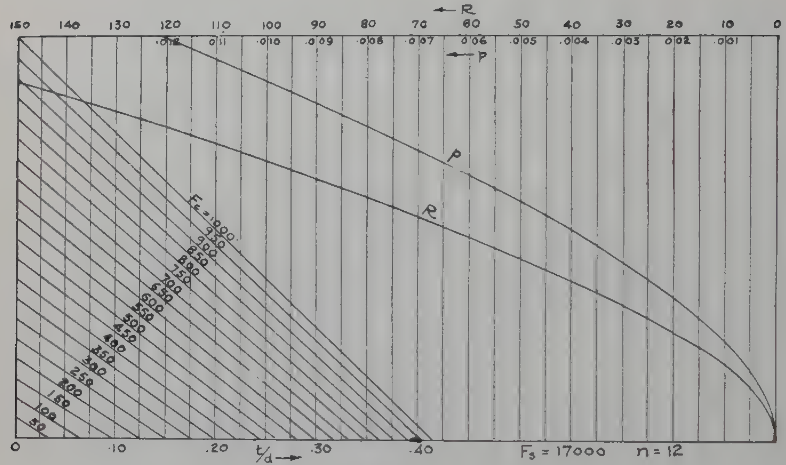

← R
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
.012
.011
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
← P
P
R
F_c = 1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
.10
.20
t/d →
.30
.40
F_s = 17000
n = 12

FIG. 4.

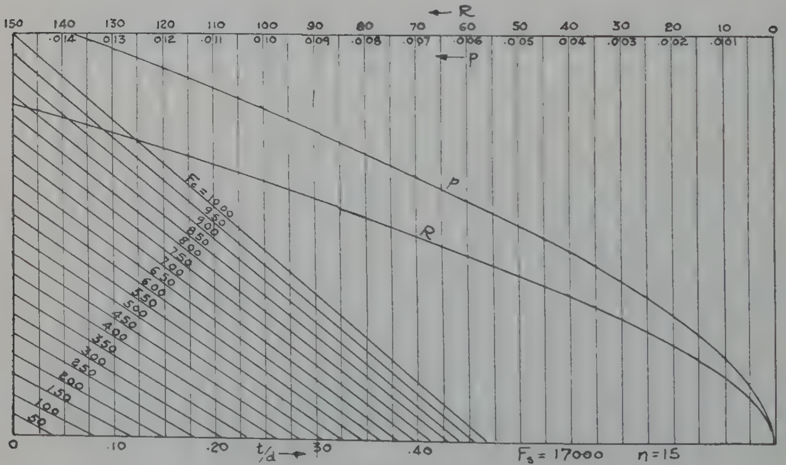

← R
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
.014
.013
.012
.011
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
← P
P
R
F_c = 1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
.10
.20
t/d →
.30
.40
F_s = 17000
n = 15

FIG. 5.

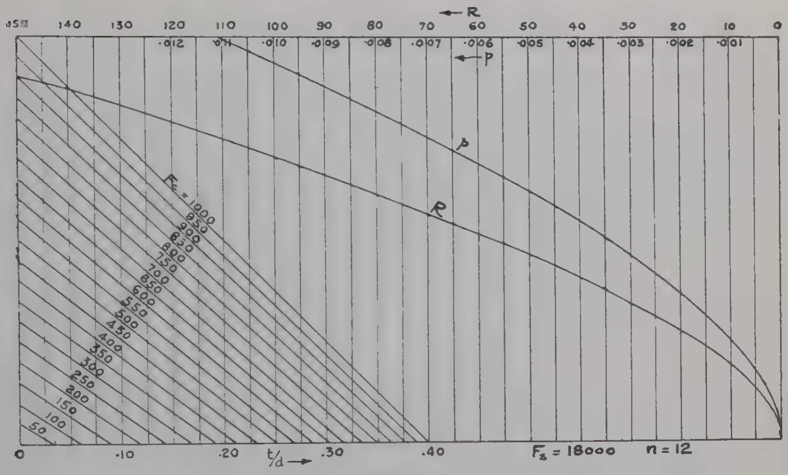


FIG. 6.

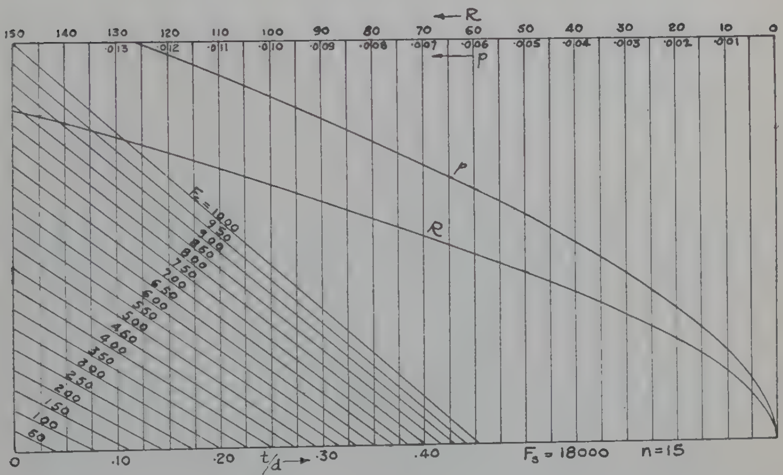


FIG. 7.

If the two moments be equal, that is to say, an area of steel $= p^1bd$ would have the same value as the area of concrete *bkd*, —

$$p^1 = \frac{jk^2}{2nr(k-1+r)}.$$

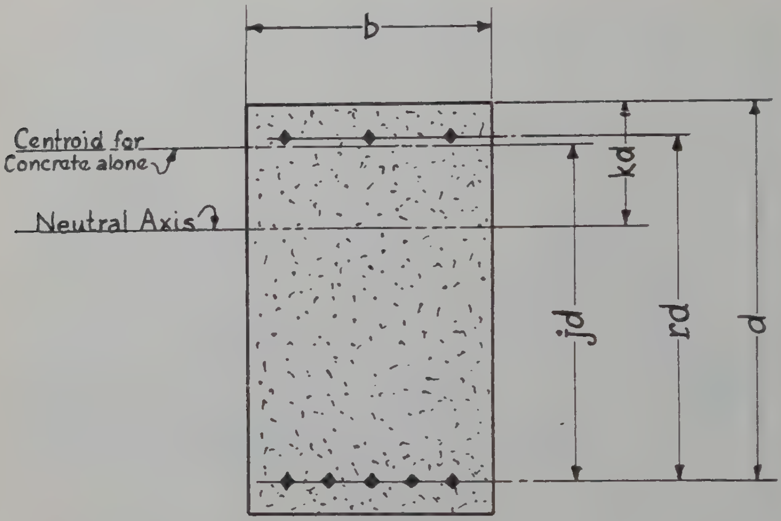


FIG. 8.

From which we see that p^1 is a constant for given stresses, etc., and for a given r.

If M = bending moment in the beam,

$$M = \tfrac{1}{2} x b d^2 k j f_c,$$

where x is the number of times which the area of concrete in compression or its equivalent area of steel in compression must be used to resist the bending moment.

Hence,

$$p^1 bd(x - 1) = p_c bd;$$

where p_c is the required ratio of steel in compression.

Therefore,

$$x = 1 + \frac{p_c}{p^1};$$

and the formula becomes

$$M = \left(1 + \frac{p_c}{p^1}\right) bkjd^2 \frac{f_c}{2} = (p_c + C_2) \frac{bd^2}{C_1}.$$

Hence, $$p_c = \left(\frac{MC_1}{bd^2}\right) - C_2 \text{ and } d = \sqrt{\frac{MC_1}{b(p_c + C_2)}}.$$

The moment of resistance of the steel in tension corresponding to the concrete in compression $= p_1bjd^2f_s$.

The moment of resistance of the steel in tension corresponding to the steel in compression $= p_2brd^2f_s$.

If the two moments be equal, then $p_1j = p_2r$.

Now, $M = xp_1bjd^2f_s$,

where x is the number of times which p_1jbd^2 or its equivalent p_2rbd^2 must be used to resist the bending moment.

Hence, $(x-1)p_2brd^2 = p_3brd^2$.

Therefore, $p_3 = (x-1)p_2 = (x-1)p_1\frac{j}{r}$.

And $x = \left(\frac{p_3r}{jp_1}\right) + 1 = 1 + \frac{p_c}{p^1}$.

Therefore, $p_3 = p_cp_1\frac{j}{p^1r} = C_3p_c$.

And, finally, total area of steel in tension $= (p + C_3p_c)bd$, where p is the ratio of steel in tension for a beam which has no steel in compression, and p_c is the ratio of steel in compression as found in one of the equations above. It should further be noticed that jd, in the above equations, is the distance of the centroid of the compressive forces in the concrete *alone* from the center of gravity of the steel in tension.

TABLE 1.

F_c.	k.	p.	R.
1000	.400	.01110	174.00
950	.388	.01020	160.00
900	.376	.00950	149.00
850	.362	.00850	134.00
800	.348	.00770	123.00
750	.334	.00700	112.00
700	.316	.00620	100.00
650	.302	.00550	89.00
600	.286	.00480	78.00
550	.268	.00410	67.00
500	.250	.00350	59.00
450	.231	.00290	48.00
400	.211	.00230	38.50
350	.190	.00190	32.00
300	.167	.00140	24.00
250	.143	.00100	17.00
200	.118	.00065	11.00
150	.091	.00039	6.80
100	.062	.00017	3.00
50	.032	.00005	0.89

$F_s = 18\,000$. $n = 12$.

TABLE 2.

$F_s = 18\,000$	$n = 15.$			$n = 12.$		
	$C_1.$	$C_2.$	$C_3.$	$C_1.$	$C_2.$	$C_3.$
$F_c = 600$	.000167	.0131	345	.000133	.0117	440
	186	.0146	316	144	.0128	410
	208	.0163	289	158	.0141	380
	237	.0185	260	174	.0156	350
	271	.0212	233	185	.0175	320
	315	.0246	205	222	.0198	290
	375	.0293	176	253	.0226	260
	455	.0356	148	293	.0262	230
	580	.0453	119	347	.0310	200
$F_c = 650$	.000154	.0136	378	.000120	.0121	482
	170	.0150	350	131	.0133	448
	188	.0167	322	144	.0146	417
	212	.0188	293	159	.0161	387
	240	.0213	263	176	.0178	357
	276	.0245	234	198	.0200	323
	323	.0286	206	223	.0226	295
	386	.0342	176	257	.0260	263
	470	.0417	148	296	.0300	233
$F_c = 700$	.000148	.0141	410	.000111	.0125	522
	163	.0155	380	121	.0137	487
	181	.0172	350	132	.0149	457
	202	.0192	320	145	.0164	425
	227	.0216	296	160	.0181	393
	258	.0246	263	178	.0202	362
	299	.0285	232	200	.0226	330
	350	.0334	202	227	.0256	300
	422	.0402	173	260	.0294	267
$F_c = 750$	.000132	.0146	445	.000101	.0130	560
	144	.0160	414	111	.0141	530
	159	.0177	383	122	.0154	494
	176	.0196	353	133	.0168	463
	198	.0220	323	146	.0185	432
	223	.0248	293	162	.0205	397
	255	.0283	263	180	.0228	365
	295	.0328	233	203	.0256	333
	348	.0386	203	231	.0292	300
$F_c = 800$	.000123	.0151	47	.000097	.0134	600
	134	.0165	44	104	.0145	565
	147	.0181	408	113	.0157	533
	162	.0200	377	124	.0172	496
	181	.0223	347	135	.0188	466
	203	.0250	317	149	.0207	433
	230	.0282	287	166	.0230	398
	264	.0324	257	184	.0256	366
	307	.0377	225	202	.0290	333

TABLE 2. — *Continued.*

$F_s = 18\ 000$	$n = 15$.			$n = 12$.		
	C_1.	C_2.	C_3.	C_1.	C_2.	C_3.
$F_c = 850$	.000115	.0155	505	.000090	.0137	640
	125	.0169	473	97	.0148	605
	137	.0185	443	105	.0160	572
	150	.0203	412	114	.0174	540
	166	.0225	379	125	.0191	502
	186	.0252	347	137	.0209	470
	210	.0283	316	152	.0232	433
	238	.0322	283	168	.0257	403
	274	.0370	253	188	.0287	367
$F_c = 900$	.000108	.0160	542	.000085	.0141	68
	116	.0173	512	94	.0152	645—
	127	.0189	480	99	.0164	610—
	139	.0207	447	108	.0178	575
	154	.0229	413	117	.0194	540
	171	.0254	380	128	.0212	505
	191	.0284	350—	141	.0234	467
	216	.0320	317	156	.0258	435
	247	.0366	284	174	.0288	400
$F_c = 950$	.000102	.0164	565	.000081	.0144	715
	110	.0177	535	87	.0155	680
	120	.0193	500	94	.0167	645
	131	.0211	468	101	.0180	612
	144	.0232	436	111	.0198	570—
	159	.0256	405	121	.0215	535
	177	.0285	372	132	.0235	500
	198	.0320	338	145	.0260	463
	225	.0363	306	161	.0288	430
$F_c = 1\ 000$	.00096	.0168	602	.000077	.0147	757
	104	.0182	57	82	.0158	722
	112	.0197	535	88	.0170	685
	123	.0215	500	95	.0183	650
	135	.0236	467	103	.0198	615
	148	.0260	433	112	.0216	575
	164	.0288	402	123	.0236	541
	184	.0322	368	135	.0260	502
	207	.0362	335	249	.0287	466

TABLE 3.

$F_s = 16\,000$	$n = 15.$				$n = 12.$			
	$r.$	$C_1.$	$C_2.$	$C_3.$	$C_1.$	$C_2.$	$C_3.$	$r.$
$F_c = 600$	.96	.000167	.0139	.39	.00013	.0124	.50	.96
	.94	184	.0153	.36	142	.0135	.47	.94
	.92	204	.0170	.33	156	.0148	.436	.92
	.90	228	.0190	.304	171	.0163	.404	.90
	.88	258	.0215	.274	189	.0180	.376	.88
	.86	295	.0246	.246	211	.0201	.344	.86
	.84	342	.0285	.217	238	.0226	.314	.84
	.82	453	.0377	.168	270	.0258	.280	.82
	.80	491	.0408	.16	312	.0297	.250	.80
$F_c = 650$	.96	.000152	.0144	.433	.000120	.0129	.545	.96
	.94	166	.0158	.403	130	.0140	.513	.94
	.92	184	.0175	.372	141	.0152	.482	.92
	.90	204	.0194	.343	154	.0166	.450	.90
	.88	228	.0217	.315	170	.0183	.417	.88
	.86	259	.0246	.283	188	.0203	.385	.86
	.84	298	.0283	.252	212	.0227	.354	.84
	.82	345	.0329	.222	238	.0256	.321	.82
	.80	409	.0389	.192	270	.0291	.290	.80
$F_c = 700$	.96	.000141	.0150	.460	.000110	.0133	.591	.96
	.94	153	.0163	.435	120	.0144	.557	.94
	.92	169	.0180	.402	130	.0157	.523	.92
	.90	186	.0198	.373	142	.0171	.490	.90
	.88	208	.0221	.342	155	.0187	.459	.88
	.86	233	.0248	.312	172	.0207	.425	.86
	.84	265	.0282	.280	191	.0230	.390	.84
	.82	306	.0325	.250	214	.0258	.350	.82
	.80	357	.0380	.218	241	.0290	.326	.80
$F_c = 750$	.96	.000130	.0155	.505	.000104	.0138	.630	.96
	.94	142	.0169	.473	111	.0148	.600	.94
	.92	155	.0185	.440	120	.0160	.570	.92
	.90	170	.0203	.412	130	.0174	.533	.90
	.88	189	.0225	.380	143	.0191	.497	.88
	.86	211	.0251	.348	157	.0210	.462	.86
	.84	238	.0283	.316	174	.0232	.428	.84
	.82	271	.0323	.283	192	.0256	.398	.82
	.80	313	.0372	.253	218	.0290	.360	.80
$F_c = 800$	.96	.000122	.0160	.537	.000096	.0141	.680	.96
	.94	131	.0173	.507	103	.0152	.645	.94
	.92	143	.0189	.475	112	.0164	.610	.92
	.90	157	.0207	.443	121	.0178	.573	.90
	.88	173	.0228	.412	132	.0194	.577	.88
	.86	192	.0253	.380	144	.0211	.507	.86
	.84	215	.0283	.346	159	.0233	.470	.84
	.82	243	.0320	.314	175	.0257	.437	.82
	.80	279	.0366	.282	196	.0287	.403	.80

TABLE 3. — *Continued.*

$F_s = 16\,000$	$n = 15.$				$n = 12.$			
	$r.$	$C_1.$	$C_2.$	$C_3.$	$C_1.$	$C_2.$	$C_3.$	$r.$
$F_c = 850$	.96	.000113	.0164	.570	.000089	.0144	.725	.96
	.94	122	.0177	.540	96	.0155	.685	.94
	.92	133	.0193	.507	104	.0167	.652	.92
	.90	145	.0210	.476	112	.0181	.615	.90
	.88	159	.0231	.443	121	.0196	.580	.88
	.86	177	.0256	.408	132	.0213	.547	.86
	.84	196	.0284	.378	145	.0235	.507	.84
	.82	221	.0320	.343	160	.0258	.473	.82
	.80	251	.0364	.309	177	.0286	.437	.80
$F_c = 900$	.96	.000107	.0168	.612	.000084	.0147	.773	.96
	.94	116	.0182	.575	90	.0158	.737	.94
	.92	126	.0197	.544	97	.0170	.698	.92
	.90	137	.0215	.510	105	.0184	.658	.90
	.88	150	.0235	.477	114	.0199	.625	.88
	.86	166	.0260	.440	123	.0216	.587	.86
	.84	184	.0287	.409	135	.0237	.549	.84
	.82	204	.0320	.376	148	.0260	.512	.82
	.80	232	.0361	.342	164	.0288	.475	.80
$F_c = 950$	.96	.000102	.0172	.649	.000080	.0151	.816	.96
	.94	110	.0186	.613	86	.0161	.780	.94
	.92	119	.0202	.575	92	.0173	.743	.92
	.90	129	.0219	.542	99	.0187	.701	.90
	.88	140	.0238	.510	107	.0203	.660	.88
	.86	154	.0262	.475	116	.0220	.625	.86
	.84	171	.0290	.440	126	.0239	.587	.84
	.82	190	.0321	.407	138	.0261	.551	.82
	.80	212	.0360	.372	153	.0288	.512	.80
$F_c = 1\,000$	.96	.000095	.0175	.685	.000076	.0153	.86	.96
	.94	102	.0189	.647	81	.0163	.823	.94
	.92	110	.0204	.612	87	.0175	.783	.92
	.90	120	.0222	.575	93	.0188	.745	.90
	.88	130	.0241	.543	100	.0203	.705	.88
	.86	142	.0263	.507	109	.0220	.665	.86
	.84	156	.0290	.472	119	.0240	.625	.84
	.82	173	.0321	.438	130	.0262	.587	.82
	.80	193	.0358	.402	143	.0288	.548	.80

DISCUSSION.

By W. W. Clifford, Member Boston Society of Civil Engineers, and C. H. Mangold.

The writers have read Mr. Lorente's paper with a great deal of interest. The compactness with which the data are given for the computation of T-beams, for various stresses, seems to them to be of special note. Mr. Lorente's method for the computation of beams reinforced for compression is logical and simple of application.

In the matter of compression steel in concrete beams, however, it often happens that the formulæ of the 1913 report of the " Joint Committee on Concrete and Reinforced Concrete " give a more direct solution. This occurs in the investigation of stresses in beams already designed, where the percentages of steel are fixed; and in the case of compression steel over the supports of continuous T-beams, where the size of the section is determined and the areas of steel largely influenced by other conditions of design. In these cases the percentages of steel form a more direct assumption than the stresses.

The common formulæ for j* and k* in doubly reinforced beams, as given by the " Joint Committee," are so cumbersome, however, as to be prohibitive in any but infrequent cases of actual design. A number of graphical and tabular aids for the use of these formulæ have been originated and published, but in most cases they involve the use of one or more new constants. Arbitrary "L"s or "C"s are another thing with which to burden the mind, and few people ever get well enough acquainted with such constants to gain anything but arbitrary values from curves or tables relating to them.

On the other hand, with functions like the depth of the neutral axis, the moment arm or the percentages of steel, most designers are thoroughly familiar. Curves relating to these quantities, therefore, not only give definite values, but also suggest the possibilities of change in one or more of the given functions.

On this account the writers have found the accompanying graphical solution of the standard formulæ to be simple and useful of application. (Fig. 9.) These are curves of j with p^1 and k as coördinates, superimposed on similar curves of p. These with the addition of Table 1, which is self-explanatory, make the necessary slide rule operations very simple.

---

* " Joint Committee " notation used.

These curves, as will be noted, are for three values of $\frac{d^1}{d}$, 0.05, 0.10 and 0.15, which will cover most practical cases. Their application is as follows: Let us assume the investigation of a beam which has an external bending moment of 1 625 000 in.-lb., $\frac{d^1}{d}=0.10$, $d=21$ in., $p=0.025$, $p^1=0.02$, and an area of tension steel of 6.30 sq. in.; n is assumed to be 15. Entering the middle group of curves $\left(\frac{d^1}{d}=0.10\right)$ at the top where the value of p^1 is 0.02, and dropping vertically down to the $p=0.025$ curve, we read $k=0.45$ and $j=.876$.

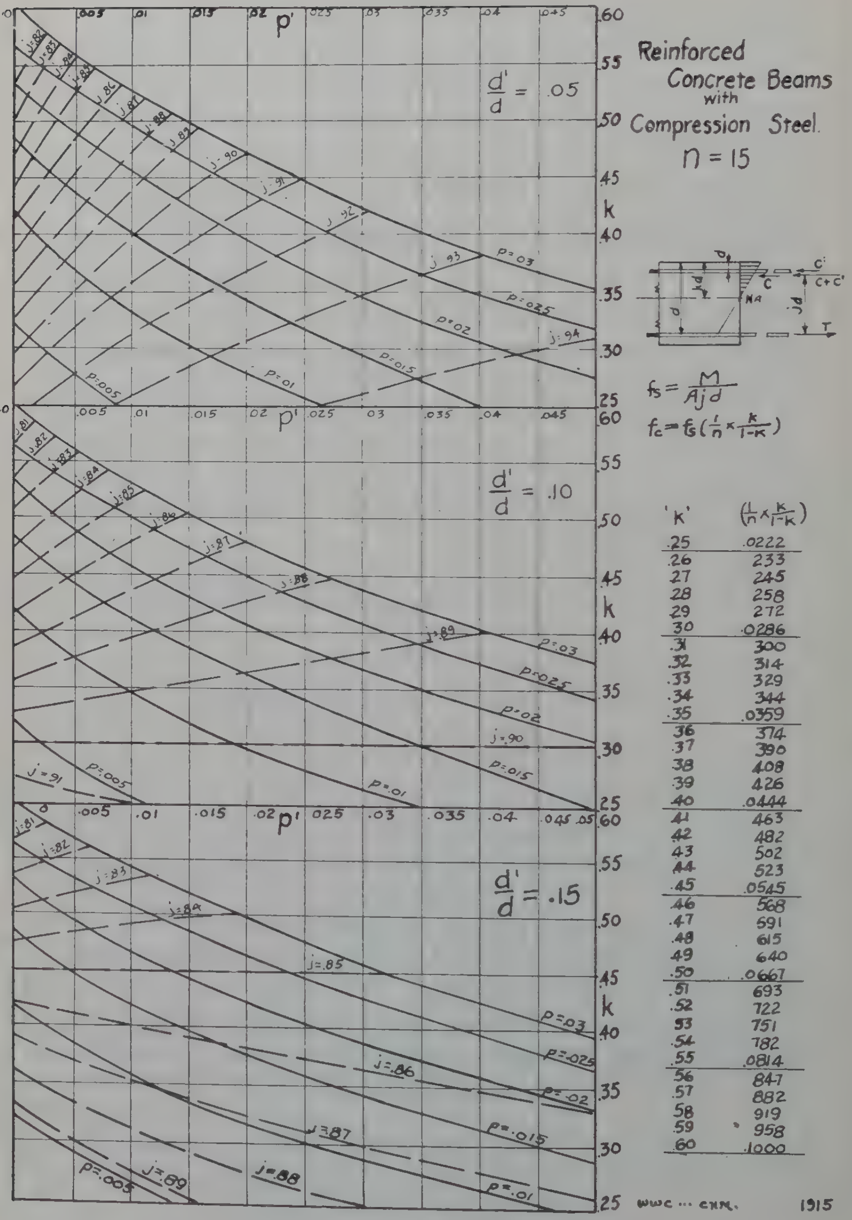
$$\text{Then } f_s=\frac{M}{Ajd}=\frac{1\,625\,000}{6.30\times 0.876\times 21}=14\,000 \text{ lbs. per sq. in.}$$

$$\text{and } f_c=f_s\left(\frac{1}{n}\,\frac{k}{1-k}\right)\left\{\begin{array}{l}\text{see Table 1}\\ k=0.45\ \left(\frac{1}{n}\,\frac{k}{1-k}\right)=0.545\end{array}\right.$$

$$=.0545\times 14\,000$$
$$=763 \text{ lbs. per sq. in.}$$

The writers recommend using the curves for the value of $\frac{d^1}{d}$ next larger than the actual value. This will be a small percentage on the safe side, but will be well within the precision of the actual work. But for special cases interpolation between the curves is easily made.

The writers trust that these curves may be of interest and use to others of the profession who have occasion to design or review concrete beams with compression steel.



Reinforced Concrete Beams with Compression Steel.
$n = 15$

$f_s = \frac{M}{Ajd}$

$f_c = f_s\left(\frac{1}{n} \times \frac{k}{1-k}\right)$

'k'	$\left(\frac{1}{n} \times \frac{k}{1-k}\right)$
.25	.0222
.26	233
27	245
28	258
29	272
30	.0286
.31	300
.32	314
.33	329
.34	344
.35	.0359
36	374
.37	390
38	408
39	426
40	.0444
41	463
42	482
43	502
44	523
.45	.0545
46	568
.47	591
.48	615
49	640
.50	.0667
.51	693
.52	722
53	751
.54	782
.55	.0814
56	847
.57	882
58	919
.59	958
.60	.1000

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FIG. 9.

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PAPERS AND DISCUSSIONS

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DISCUSSION OF GROUND WATER SUPPLIES.

By Robert Spurr Weston, Allen Hazen, Henry A. Symonds and William S. Johnson.

Mr. Weston.* — Mr. Johnson's paper has so well covered the field of ground water supply, the construction of the works, and their operation, that there is very little left for any one to say in discussion. It is good to hear a paper so full of ideas.

I think few of us realize how recent is our knowledge regarding ground water supplies. While it is true that Aristotle and some of the early Greek philosophers had the idea that the source of the ground water was the rain, which, as they expressed it, was absorbed by the mountains, and then given back to the springs and wells, the people in the Middle Ages thought that the source of ground water was the condensed steam which was produced by the seepage of the ocean water into the hot bowels of the earth. It was not until the last decade of the nineteenth century that people really began to study the subject experimentally in order to determine the laws of the flow of ground water. As Mr. Johnson states, our Massachusetts conditions, our New England conditions, with the possible exception of those which exist in the more recent deposits in the southeastern part of this state, — which are similar to those in New Jersey, — are not uniform. Except in those regions, all of the water-bearing material is heterogeneous and is not subject to those hydrological laws which have been so well worked out by Mr. Schlicter, of the Geological Survey, and others. Out West they are able to predict almost certainly what some of the sandstones will yield when wells are sunk into them. There is a story about one of the Chicago & Northwestern Railroad engineers who sank a well at 1 500 ft. and getting discouraged called in a geologist. The advice given was so precise that water was found at about 1 600 ft. as predicted.

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* Consulting Sanitary Engineer, Boston.

One of the chief advantages of ground water is its better appearance as compared with surface water. As Mr. Johnson says, it is cooler in summer and warmer in winter than the surface water. It can be used from the tap without ice, which is an advantage, and it is generally free from odor, color and objectionable taste, except when it contains iron or some of the dissolved gases from the soil. Many of the largest supplies of the world have been changed over in recent years from surface sources to ground water sources; among them, such cities as Budapest, Hamburg, Berlin, Leipsic and Dresden, all of them cities of the first class and cities which formerly were apparently well satisfied with surface water supplies. Military reasons have led many German cities to adopt the ground water supply in whole or in part; Antwerp had a surface supply which failed with the fall of Fort Woevre-St. Catherine.

Mr. Johnson applied the term " deep wells " to artesian wells also. The speaker has always been taught that deep wells are wells which are driven to a considerable depth, and artesian wells are deep wells in which water rises under pressure to a greater or less height above its source in the ground; when rising above the surface they are flowing (artesian) wells.

Mr. Johnson has emphasized a most important point, namely, the value of pumping tests. We have not always felt that the results obtained enabled us to predict the quality as well as the quantity of the water. I would cite the Middleboro water works as an example. About twenty years ago they made a pumping test and found the water to be excellent in quality and practically free from iron, and so it continued to be for several years. Then came a break; organic matter increased in the soil, the iron content rose and the water became disagreeable, and without increasing the consumption the iron has increased threefold within the last fourteen months. This increase in iron, and with it often manganese, has been the experience with a great many supplies in eastern Massachusetts. It does not seem to be the case with supplies in the western part of the state, probably due, I think, to the larger deposits of bog iron ore in the East as compared with those in the West.

Nothing is more important, as Mr. Johnson has said, than to locate the wells as far away as possible from peat bogs. Peat bogs when inundated and thus kept away from the air, ferment and the sulphur compounds in the organic matter change over to hydrogen sulphide gas. This gas will dissolve in the water, and when brought in contact with air oxidizes to sulphuric acid, which dissolves the iron and produces with organic matter a very refractory compound. This is the situation at Reading, where the iron is dissolved by the sulphuric acid. A similar case occurred at Breslau in Germany, where the sulphuric acid dissolved so much manganese that the whole works had to be shut down for a time.

We have just finished a pumping test for a supply in Worcester County testing for 100 000 gal. per day at a 200 000 gal. rate during the whole test week. The whole cost of ten wells including the test was $1 500.

I think Mr. Johnson is to be congratulated upon this very clear presentation of an important and rather neglected subject in water supply engineering.

Mr. Hazen.* — I have been greatly interested in Mr. Johnson's paper. Twenty years ago I had the pleasure and privilege of presenting to this Society some ideas in regard to ground water supplies, and I am pleased to hear from Mr. Johnson that many of the points that I then made are still good. On the other hand, Mr. Johnson's paper shows that the methods of finding and developing such supplies have been greatly improved in recent practice in Massachusetts.

As a general proposition I have been rather skeptical of pumping tests as a means of determining permanent yielding capacities of supplies. Without attempting to give from memory the exact capacities, the histories of a few plants may be instructive as bearing upon the reliability of pumping tests.

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* Hazen & Whipple, Consulting Engineers, New York.

In one case a well plant was built as an auxiliary plant some fifteen or eighteen years ago. It was built under a contract with a guarantee to produce three million gallons per day, and it did produce the full quantity for the guaranteed period, which was I think, one year. The next year it fell somewhat short of the guaranteed capacity, but, of course, the guarantee had expired; the following year it fell still further short, and in the course of a few years the output had dropped to about one quarter of the original amount, and that amount was steadily maintained during a ten-year period. The explanation was that the valley in which this plant was located contained a big underground reservoir of pervious material. This reservoir held enough water to maintain the output during the first year, and to furnish a considerable but reducing quantity thereafter during several years. When the natural reservoir had been drained as far as the wells were capable of draining it, the output was reduced to the amount which resulted from the rainfall on the tributary area, which proved to be only a fraction of the original amount. A year's pumping test ordinarily would be considered to be an exhaustive one, but in this case it did not prove to be. The permanent yield was very much less than had been indicated by it.

In another case a ground water supply served a prosperous and growing community. As the years went by, other and deeper wells were driven from time to time to get more water. The ground water level gradually became lower, the pump pits were deepened, and afterward air lifts were put in to take the water lower. During a period of fifteen or twenty years the ground water level was gradually lowered until now it is probably from fifty to one hundred feet lower than it naturally was over an area of many square miles. This is another case of a reservoir of very great capacity which has been gradually drained and emptied by pumping water out of it. The water that has been taken has been valuable and has permitted the company that exploited it to pay for their works and pay dividends. The development was good and profitable, although not a permanent one. The water that has been taken is comparable with the coal that is taken from a mine: there is about so much of it, and when it is gone another source of supply must be found.

In still another case a ground water supply near salt water yielded through a considerable term of years an abundant supply of water of excellent quality. Ultimately the water became brackish and not suitable for further service. In this case there was no reduction of ground water level during the period of successful pumping. The explanation is that large layers of pervious material existed below the sea level, but these were filled with fresh water of good quality which represented the accumulation of many years of surface run-off from a small tributary area. As this water was drawn by the wells the water level was not lowered because sea water came in to take its place in the voids of the pervious material. A full supply was easily maintained without lowering the ground water level until the fresh water had been so drawn out that salt water commenced to reach the wells. After that the supply was practically useless.

I cite these as illustrations of cases where pumping tests have continued for much longer periods than are usually thought sufficient to demonstrate all the conditions that there are, and which have nevertheless failed to show the permanent yielding capacities.

In California there has been a recent development in ground water supplies that has greatly increased their practical value; that is, the use of electricity for operating pumps to get water out of the wells. The electricity comes from water power in the Sierras. The electrical apparatus has been perfected so that it not only takes care of itself with only occasional inspection, but is able to stop and start itself according to the demand for water. In general a pump is used for each well, but sometimes the wells are more numerous than the pumps, and the motor and pump are taken from well to well in rotation to secure the fullest and most convenient development and use of the supply.

Mr. Symonds.* — There is one matter which I would like to mention, which Mr. Johnson referred to, and that is the question of large pipe wells in place of strainer point wells. The need of something of this kind arose in some underground water supplies on Cape Cod. As you probably know, the Cape is largely a sand formation. There is more or less gravel, but that is mixed with a good deal of fine sand, and my experience has been that it is necessary to use strainer points of some kind in most parts of the region. We have found that after a comparatively few years strainer points of all descriptions give more or less trouble. The ordinary strainer point, such as was shown on the screen, seems to form a sort of scale over the outside of the small wire screens which practically puts them out of commission, with such water which might be found on the Cape, in about three years. We have tried to find some remedy for this trouble, which was becoming very pronounced with the wells in one plant. We studied the feasibility of the large well, but conditions were not such as to warrant putting in a large well without an expensive test, which we hesitated to make. In trying to devise some scheme by which we could get water into the wells without having the trouble of clogging up fine screens and not having to go to the expense of a large well, we undertook to sink a series of small wells, each about two feet in diameter.

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* Consulting Engineer, The Hanscom Construction Company, Boston.

The use of such wells is not new, but some of the features of the wells which we are using at the present time may be a little different from those used before for this purpose.

We find it possible to sink these wells by dredging out the interior so long as we take certain precautions in regard to keeping the pipes together. We started using cement pipes with bells. This method was satisfactory in some sections but did not work well in others, as the lower pipes sometimes dropped away from those above. But we finally devised a series of clamps which have given good results. It becomes evident as the dredging takes place in the interior of these wells that the pipes alone do not go down, causing friction on the sides, but that a certain volume of the surrounding earth, varying from six inches to a foot, gradually works down with the pipe.

These wells on the Cape have proven very satisfactory and we are now using them in some other places. In places where it has been impossible to get water with any form of small pipe well where there is a great deal of quicksand, these wells are doing good work. There are certain problems in regard to the operation and keeping the quicksand out which we are now working on, but we believe that the field for this kind of well is a fairly broad one and, developed as it should be, will help out the underground water supplies. There are a great many towns in Massachusetts where a great deal of difficulty is being experienced with well systems that might be helped by this form of well.

In regard to the pumping tests which, as Mr. Hazen has shown by some very good examples, are in many cases unsatisfactory, it seems to me, nevertheless, that for small plants such as are being largely put in at the present time in this section of the country, they have a great many advantages as well as some disadvantages, and as an illustration I might cite the case of Merrimack, N. H., where we made a lot of tests two or three years ago and found some rather unusual conditions. The water was cold, about 42° or 43°. It was analyzed and reported as very high grade by the New Hampshire State Board of Health. The Merrimack people were so well pleased with the indications that a pumping test seemed unnecessary. We half believed this ourselves, but did not think best to take the chances, so we started pumping from about eight wells something like 100 000 gallons in twenty-four hours. The quality and quantity were both very uniform for about three days. Suddenly the water became warm, the temperature going up to about 60°, I believe. The water changed entirely in its nature and evidently came through from a river in the vicinity. The pumping test may not prove that the supply is going to hold out for all time, but it does show *some* of the dangers which the underground water supplies are subject to.

Mr. Johnson* (*by letter*). — Mr. Hazen has apparently failed to note what I tried to emphasize as one of the most important parts of the pumping test, namely, the observation of the height of the ground water in the vicinity during and after the test. The cases cited by Mr. Hazen are excellent illustrations of the value of the properly conducted pumping test. If such a test had been made in these instances and the data secured, which is necessary for the proper interpretation of the test, what actually happened could have been foretold with accuracy.

---

* Author's closure.

If water is stored in a pocket of porous material beneath the surface of the ground with little inflow into it, there should be no difficulty in determining this fact by lowering the level of the water in the pocket and observing the recovery of the water. Several such cases were referred to in the original paper, and the diagrams illustrating them were shown on the screen but were not reproduced in the JOURNAL.

In the case of water being drawn from a salt-water source, observations of the ground water level would undoubtedly have shown that water was being drawn from the direction of the salt water, and it might reasonably have been expected, if the ground water level was held below the sea level, that ultimately some salt would be drawn into the wells.

The cases cited, instead of showing the weakness of the pumping test, show most conclusively the value of such a test, for in all of the cases the failure of the supply might have been predicted.

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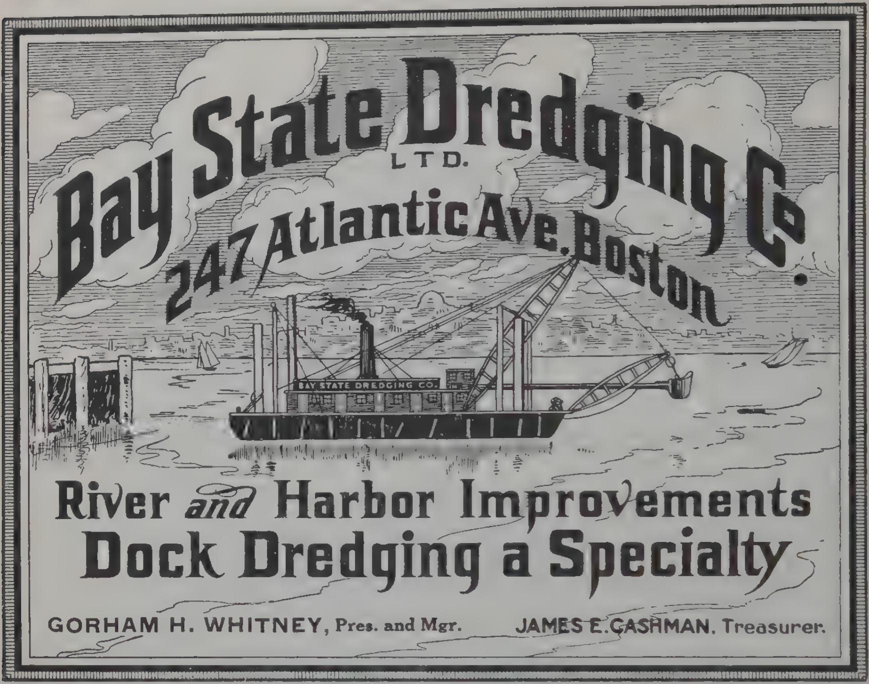

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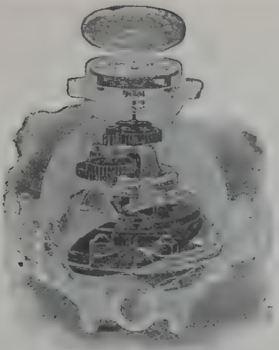

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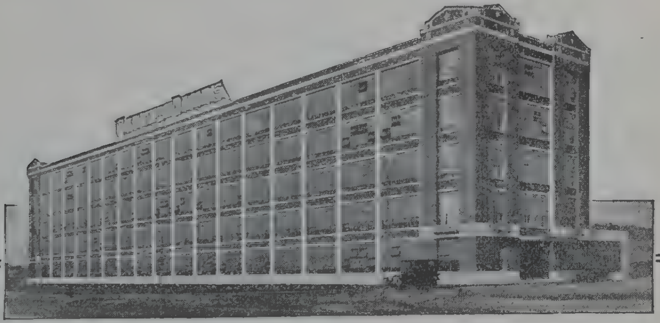

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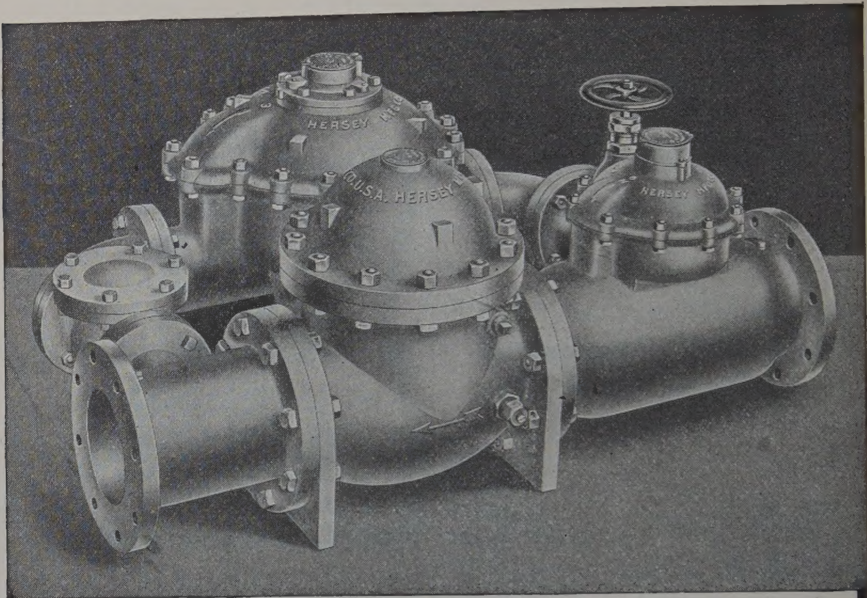

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